PAPER MAKING APPARATUS HAVING PRESSURIZED CHAMBER

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BACKGROUND OF THE INVENTION

1. Field of the invention.

The present invention relates to a pressing apparatus, and more particularly, to a pressing apparatus for de-watering a continuous web, such as a paper web.

2. Description of the related art.

A paper making-machine is used for making a fiber web, or continuous web, from a fiber slurry. The fiber slurry is typically in the form of fibers, such as wood fibers, which are suspended in water. The fiber slurry is introduced into a headbox. The function of the headbox is to convert the slurry into a highly uniform flat jet of liquid, which is drained on forming fabric, which creates the fiber (paper) web. In order for a uniform sheet of paper, it is desired to create a highly turbulent flow area within the headbox in order to break up flocks in the slurry. In general, the higher the turbulence, the smaller the flocks, and thus, the more uniform the sheet of paper. The draining also effects the quality of the sheet, and the size and cost of the machine.

Accordingly, a need exists for an improved apparatus and method for forming a fiber web, such as a paper web, on a forming fabric.

SUMMARY OF THE INVENTION

The present invention is directed to an apparatus and method for forming a fiber web, such as a paper web, on a forming fabric in a pressurized chamber.

One aspect of the invention is directed to an apparatus for making paper using a forming fabric. A plurality of rollers are arranged for cooperative rotation, each of the plurality of rollers having a first circular end, a second circular end and a cylindrical middle surface. The plurality

of rollers are positioned to define a corresponding plurality of nips, the forming fabric being processed through at least two of the plurality of nips, and at least a first roller of the plurality of rollers having at least one void formed in the cylindrical middle surface. First and second sealing panels engage the first and second circular ends of each of the plurality of rollers. The first and second sealing panels and the plurality of rollers define a chamber. A conduit is positioned in the chamber and has a plurality of distribution holes extending across a width of the forming fabric. A pressure source is fluidly coupled to the distribution conduit to supply a pressurized flow of a slurry in the chamber across a width of the forming fabric to form a continuous web. The continuous web is formed on the forming fabric at a location in the chamber where the chamber fluidly communicates with the at least one void formed in the cylindrical middle surface

Another aspect of the invention is directed to a method of forming a continuous web on a forming fabric, comprising the steps of providing a pressurized chamber; processing the forming fabric through the pressurized chamber; and distributing a pressurized flow of a slurry having a first composition in the pressurized chamber across the width of the forming fabric to form the continuous web.

An advantage of the present invention is that the forming area can be shortened over that of a typical headbox arrangement, and the forming area can be controlled by the application of pressure within the chamber.

Another advantage is that the present invention can be joined seamlessly with a cluster press, such as the multi-roller arrangement shown in Fig. 1, as to form a compact paper machine.

Another advantage is that the present invention can incorporate multiple chambers to form multi-ply paper, to successively form a first layer of a first material, de-water it, and form a subsequent layer in a subsequent chamber out of a second material.

Yet another advantage of the present invention is that the continuous web is formed on a forming fabric in a closed pressurized chamber, thereby reducing the possibility of contamination at the early stages of the continuous web (fiber web) forming process.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become more apparent and the invention will be better understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a partially schematic side view of an embodiment of the present invention;

Fig. 2 is perspective side view of the roller configuration of the embodiment of Fig. 1;

Fig. 3 is a partial front view of the roller configuration of the embodiment of Fig. 1;

Fig. 4 is a schematic illustration of a variant of an end sealing panel of the present invention;

Fig. 5 is a schematic illustration of a variant of another end sealing panel of the present invention;

Fig. 6 is an exaggerated side view of a variant of a main roller profile of the invention;

Fig. 7 is a schematic illustration of a variant of the single chamber embodiment of Fig. 1; and

Fig. 8 is a schematic illustration of an embodiment of the invention including two chambers.

Fig. 9 is a schematic illustration of another embodiment of the invention.

Fig. 10 is a schematic illustration of still another embodiment of the invention.

Fig. 11 is a schematic illustration of the distribution of a slurry in a pressurized chamber

4

onto a forming fabric.

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrates preferred embodiments of the invention, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings and particularly to Fig. 1, there is shown a press arrangement 10 which is particularly useful in paper making. Press arrangement 10 includes a frame 12, a loading cylinder 14, a press roller assembly 16, a tensioning assembly 18, a membrane 20 and a control unit 21.

Frame 12 includes a main frame 22, an upper pivot frame 24, a lower pivot frame 26, an upper pivot arm 28 , a lower pivot arm 30 and a pair of side frames 32, 33. Side frame 32 is shown with a portion broken away to expose an interior portion of side frame 33. Pivot frames 24, 26 are fixedly attached, such as by welds or bolts, to main frame 22. Pivot arms 28, 30 are pivotally mounted to pivot frames 24, 26, respectively, by a plurality of pivot pins 34 in a conventional manner. Each of the pivot arms 28, 30 have a first end 36, 38, respectively. adapted to mount opposing ends 40, 42 of loading cylinder 14 via pins 44. Each of the pivot arms 28, 30 has a second end 46, 48, adapted to fixedly mount, such as by welds or bolts, bearing housings 50, 52, respectively. First and second side frames 32, 33 are mounted to opposing sides of main frame 22.

Pressing roller assembly 16 includes a plurality rollers 60, 62, 64, 66 (four rollers as shown) arranged for cooperative rotation in frame 12. By cooperative rotation, it is meant that a rotational velocity at the circumferential surface of each of the rollers 60, 62, 64, 66 together are

5

substantially equal, with essentially no slippage between the roller surfaces. For convenience, sometimes rollers 60, 62 will be referred to as main rollers and rollers 64, 66 will be referred to as cap rollers.

As shown in Figs. 2 and 3, generally, each of the rollers 60, 62, 64, 66 are closed hollow cylinders having a first circular end 68, 70, 72, 74, respectively, a second circular end 76, 78, 80, 82, respectively, and a cylindrical middle circumferential surface 84, 86, 88, 90, all being radially symmetrical about an axis of rotation 92, 94, 96, 98, respectively. A set of seals 99 may be attached to first circular ends 68, 70, 72, 74 and second circular ends 76, 78, 80, 82. An axial extent of each of the main rollers 60, 62 and cap rollers 64, 66 together are arranged in parallel. Preferably, a circumference of either of cap rollers 64, 66 is smaller than a circumference of either of main rollers 60, 62. As shown in Fig. 1, the rollers 60, 62, 64, 66 are positioned to define a corresponding number of roller nips 100, 102, 104, 106.

Cap rollers 64, 66 are used to create a seal along the axial extent of main rollers 60, 62 at roller nips 100, 102, 104, 106. Each of rollers 60, 62, 64, 66 may include an elastic coating, such as rubber, to aid in sealing at the roller nips. Sealing at roller nips 100, 102, 104, 106 requires relatively uniform pressure along all roller nips 100, 102, 104, 106. With the likely deflection of main rollers 60,62, due to the exertion of force thereon by cap rollers 64, 66, some mechanism is needed to aid in providing uniform nip pressure at roller nips 100, 102, 104, 106. Accordingly, cap rollers 64, 66 can use hydraulic pressure and a series of pistons within the roller shell of rollers 64, 66 to press the roller shell of rollers 64, 66 into the roller shell of main rollers 60, 62 to provide uniform pressure at the associated nips. Alternatively, a crowned cap roller could be used.

6

As shown in Fig. 3, first and second side frames 32, 33 include first and second sealing panels 108, 110 respectively, mounted to an interior side thereof. First and second sealing panels 108, 110 are forced by side frames 32, 33 to engage a portion of first circular ends 68, 70, 72, 74 and a portion of second circular ends 76, 78, 80, 82 respectively, of rollers 60, 62, 64, 66 of pressing roller assembly 16 to define a chamber 112 (shown in Figure 4), and to effect end sealing of chamber 112. Optionally, at least one tension bar 113 is connected between first sealing panel 108 and second sealing panel 110 in chamber 112 (shown in figure 4). In some embodiments, first and second sealing panels 108, 110 are flexible and are structured and adapted to substantially conform to the shape of first circular ends 68, 70, 72, 74 and second circular ends 76, 78, 80, 82 , respectively, of rollers 60, 62, 64, 66 . To further aid in the sealing of chamber 112 (shown in figure 4), seals are formed between first and second sealing panels 108, 110 and first and second circular ends 68, 70, 72, 74 and 76, 78, 80, 82, respectively. Such seals can include mechanical seals and fluid seals.

Main rollers 60, 62 are fixedly rotatably mounted to side frames 32, 33 using conventional bearing mounting assemblies, such as those containing roller bearings or bushings. In this context, fixedly rotatably mounted means that the axes 92, 94 (shown in figure 2) of rollers 60, 62 are not shifted in location with respect to main frame 22 and side frames 32, 33 following installation, but rotation about axes 92, 94 (shown in figure 2) is permitted.

Preferably, main roller 60, which fluidly communicates with chamber 112 via membrane 20, includes at least one void in the form of a groove, a hole and a pore formed in its middle circumferential surface to facilitate a pressure differential across membrane 20 (shown in figure 1) and any intervening material, such as continuous web 140 (shown in figure 1). Also, it is preferred that main roller 62, which does not fluidly communicate with chamber 112 (shown in figure 4) via membrane 20 (shown in figure 1), not include any such void in its middle circumferential surface. Each of the rollers may include an elastic coating, such as

rubber over all or part of their roller surface, to aid in the sealing of chamber 112 at roller nips 100, 102, 104, 106.

Cap rollers 64, 66 are rotatably mounted to bearing housings 50, 52, respectively. However, the axes of rotation 96, 98 of rollers 64, 66 are moveable with respect to main frame 22 via pivot arms 28, 30, respectively, to effect a loading of press roller assembly 16. Since a circumference, and a corresponding diameter, of either of cap rollers 64, 66 is preferably smaller than a circumference, and a corresponding diameter, of either of main rollers 60, 62, the forces generated on cap rollers 64, 66 are reduced, thus allowing smaller structures to contain the forces within chamber 112.

For example, cap rollers 64, 66, being relatively smaller, require lower actuating force than would a relatively larger counterpart cap roller. If the diameters of cap rollers 64, 66 are one-third the diameters of main rollers 60, 62, the forces exerted on cap rollers 64, 66 can be reduced by 40 percent compared to the forces on main rollers 60, 62.

In general, the closer the distance between main rollers 60 and 62, and the greater the difference in diameters between main rollers 60, 62 and cap rollers 64,66, the greater the difference in forces exerted on frame 12 by main rollers 60, 62 and cap rollers 64,66. This arrangement allows the support structure, e.g. frame 12, for press roller assembly 16 to become simpler. For example, with most of the force exerted by the relatively larger main rollers 60,62, main rollers 60,62 are mounted on bearings fixedly attached to side frames 32,33, which in turn are fixedly attached to main frame 22. By structurally tying main rollers 60 and 62 together, and fixing their relative positions, the major forces within the press arrangement 10 are contained within a relatively simple mechanical structure.

8

In order to maintain membrane 20 at a proper operating tension, tensioning assembly 18 is mounted to main frame 22. Tensioning assembly 18 includes a tension cylinder 114 and a tension roller 116. Tension roller 116 is rotatably coupled to tension cylinder 114, which moves tension roller 116 in a direction transverse to an axis of rotation of tension roller 116.

As shown in Fig. 1 in relation to Fig. 2, membrane 20 travels in the direction of arrow 118 and is routed over a portion of circumferential surface 88 of cap roller 64, passes into inlet roller nip 100, passes over a portion of circumferential surface 84 of main roller 60 within chamber 112, passes out of outlet roller nip 102, passes over a portion of circumferential surface 90 of cap roller 66, and passes around about half of the circumferential surface of tension roller 116. Preferably, membrane 20 is a continuous belt made of a semipermeable material structured and adapted to have a predetermined permeability which permits a predetermined fluid flow therethrough. Also, preferably semipermeable membrane 20 is both gas permeable and liquid permeable to a limited degree. Furthermore, membrane 20 is structured and adapted to aid in the sealing of chamber 112 at inlet nip 100 and outlet nip 102. In chamber 112, after being pressurized, the combined effect of inlet nip 100, membrane 20 passing circumferentially around main roller 60, and outlet nip 102 is to effectively form a single expanded nip 115 for applying a mechanical pressing force on main roller 60 and any intervening material placed between membrane 20 and main roller 60. Thus, membrane 20 communicates with pressurized chamber 112 and main roller 60 to simultaneously effect both a predetermined fluid flow through and a mechanical pressing force on the intervening material.

In preferred embodiments, membrane 20 is made of a rubberized fabric about 0.1 inches thick, or less, and is made semipermeable by forming a plurality of holes 117 (see Fig. 6) through the fabric having a size, shape, frequency and/or pattern selected to provide the desired

9

permeability. Preferably, the plurality of holes are formed by a laser. The permeability is selected to be greater than zero and less than about five CFM per square foot as measured by TAPPI test method TIP 0404-20, and more preferably, is selected to be greater than zero and less than about two CFM per square foot. Thus, semipermeable membrane 20 is both gas permeable and liquid permeable to a limited degree.

Control unit 21 includes a controller 120, a pneumatic source 122, a fluid source 124, a differential pressure source 125 and a sensor assembly 126.

Preferably, controller 120 includes a microprocessor and memory for storing and executing a control program, and includes an I/O device for establishing input/output communications and data transfer with external devices. Controller 120 can be, for example, an industrial programmable controller of a type which is well known in the art.

Pneumatic source 122 includes a plurality of individually controllable outputs. Pneumatic source 122 is fluidly coupled to loading cylinder 14 via conduit 128. Pneumatic source 122 is also fluidly coupled to tension cylinder 114 via conduit 130. While the preferred working fluid to operate cylinders 14, 114 is compressed air, those skilled in the art will recognize that the pneumatic system could be converted to another fluid source using another gas, or a liquid working fluid.

Fluid source 124 is fluidly coupled to chamber 112 via conduit 132. The type of fluid is selectable by the user depending the type of material that press arrangement 10 is processing. For example, in some applications, it may be desirable to use compressed dry air to pressurize chamber 112 to a predefined pressure, which in preferred embodiments of the invention, is a pressure greater than 30 p.s.i. above pressure the differential pressure of differential pressure source 125. In other applications, it may be desirable to use a pressurized gas, such as a heated

gas, or a liquid, such as water, or a liquid solution.

In the embodiment of Fig. 1, fluid flows into chamber 112 via conduit 132 and flows out of chamber 112 via the voids, e.g. grooves, holes or pores, formed in middle circumferential surface 84 of main roller 60. The voids in main roller 60 communicate with differential pressure source 125 via a conduit 133. Differential pressure source 125 can be, for example, a vacuum source, a pressure source operating at a pressure lower than the pressure in chamber 112, or simply a vent to the atmosphere, which is coupled via conduit 133 to the interior of roller 60 to effect evacuation of the voids.

Alternatively, no venting via conduit 133 may be required if main roller 60 includes grooved voids, and the grooves communicate with atmospheric pressure. Similarly, venting via conduit 133 may be eliminated if the roller voids, such as blind holes, are large enough, and if they enter into the nip at a pressure lower than chamber pressure. In this case, the voids will act like a differential pressure source until the voids reach the chamber pressure. The void size can be selected to control the efficiency of the de-watering process.

The pressurized chamber 112 includes an inherent pressure relief, in that excessive pressure buildup in chamber 112 will result in one or more of rollers 60, 62, 64, 66 opening to bleed off the pressure, rather than undergoing catastrophic failure.

Controller 120 is electrically connected to pneumatic source 122 via electrical cable 134 to selectively control the fluid output thereof to independently control the operation of loading cylinder 14 to provide loading to press roller assembly 16 and to independently control the operation of tension cylinder 114 to provide a predetermined tension on semipermeable membrane 20.

Controller 120 is electrically connected to fluid source 124 via electrical cable 136. Controller 120 is further electrically connected to sensor assembly 126 via electrical cable 138. Sensor assembly 126 includes one or more sensing mechanisms to provide to controller 120 electrical feedback signals representing one or any combination of a pressure, a temperature or other environmental factor within chamber 112. Controller 120 processes the feedback signals to generate output signals which are supplied to fluid source 124 to selectively control the fluid output thereof.

In operation, controller 120 processes feedback signals received from sensor assembly 126 to control a pressure of pressurized chamber 112, preferably to a pressure greater than 30 p.s.i. above the pressure of differential pressure source 125. Rollers 60, 62, 64, 66 are rotated with little or no slip between them, and membrane 20 is driven at the same velocity as the surface velocity of rollers 60, 62, 64, 66. A continuous web, or paper web, 140 and a web carrying layer 142 are started into inlet roller nip 100 in the direction of arrow 143 and is guided by membrane 20 through expanded nip 115 to outlet roller nip 102. Membrane 20 is positioned within roller assembly 16 to be adjacent a first side 144 of continuous web 140 to effectively separate continuous web 140 from direct communication with pressurized chamber 112. In other words, the fluid in chamber 112 cannot act on continuous web 140 except through membrane 20. Web carrying layer 142 is positioned to contact cylindrical middle surface 84 of main roller 60 and to contact a second side 146 of continuous web 140.

Membrane 20 is structured and adapted to have a permeability which permits a predetermined fluid flow therethrough to continuous web 140, and communicates with pressurized chamber 112 and at least one void of main roller 60 to generate a pressure difference across membrane 20 and continuous web 140. This pressure drop results in a mechanical

\ 8

pressing force being applied to continuous web 140, which helps to consolidate it. Thus, membrane 20 communicates with pressurized chamber 112 and main roller 60 to simultaneously effect both a predetermined fluid flow through and a mechanical pressing force on continuous web 140, in combination, to promote enhanced de-watering of continuous web 140.

The invention is particularly advantageous when the dry content of continuous web 140 prior to de-watering is higher than about 6 percent and lower than about 70 percent, and when the basis weight of continuous web 140 is higher than about 25 g/m^2.

Web carrying layer 142 preferably has a thickness of about 0.1 inches or less, and may be a felt, or alternatively, may include a felt positioned adjacent a hydrophobic layer, wherein the hydrophobic layer is positioned adjacent second side 146 of continuous web 140. Preferably, web carrying layer 142 includes a felt layer 142A integral with a hydrophobic layer 142B, wherein hydrophobic layer 142B transports water via capillary action away from continuous web 140 to be received by felt layer 142A (see Fig. 6). The hydrophobic layer 142B provides an anti-rewetting effect, thereby avoiding water flowing back into continuous web 140.

The relative amounts of mechanical pressure applied to continuous web 140 is effected by factors such as the chamber pressure in chamber 112, the permeability of semipermeable membrane 20, and the permeability of continuous web 140. The fluid flow, preferably air, through continuous web 140 is effected by factors such as the chamber pressure in chamber 112, the permeability of semipermeable membrane 20, and the size (e.g., length) of chamber 112. The dynamic fluid pressure in pressurized chamber 112 is controlled based upon the monitoring of the chamber pressure by sensor assembly 126. Sensor assembly 126 senses a pressure within chamber 112 and provides a pressure feedback signal to controller 120. Controller 120 processes the pressure feedback signal to generate a pressure output signal which is supplied to fluid source

13

124 to selectively control the fluid output thereof to control a pressure of pressurized chamber 112 to a predetermined pressure, preferably to a pressure greater than 30 p.s.i. above the pressure of differential pressure source 125. If a temperature in relation to pressure within pressurized chamber 112 is of concern, sensor assembly 126 may be adapted to sense a temperature within chamber 112 and provide a temperature feedback signal to controller 120. Controller 120 processes the temperature feedback signal, along with the pressure feedback signal, to generate output signals which are supplied to fluid source 124 to regulate the pressure and temperature in pressurized chamber 112.

Controller 120 also controls the loading of main rollers 60, 62 by cap rollers 64, 66 by controlling an amount of pressure that loading cylinder 14 applies to upper and lower pivot arms 28, 30. Preferably, the amount loading of main rollers 60, 62 is related to a pressure in pressurized chamber 112, which is monitored by a pressure sensor of sensor assembly 126. The loading may include a bias loading in addition to a loading proportional to the pressure in chamber 112.

Of course, variations of the embodiment described above are possible. For example, and referring to Fig. 4, to maintain the end sealing of chamber 112, and to prevent wear between sealing panels 108, 110 and rollers 60, 62, 64 and 66, a lubricating and sealing fluid like air or water, or some viscous fluid, can be forced into a plurality of seal ports 148 via a conduit ring 150 coupled to a fluid source 152 via conduit 153. Pressurized fluid source 152 is electrically coupled to controller 120 via electrical cable 155, and is controlled thereby. Seal ports 148 in sealing panels 108, 110 are located to face the ends of the rollers 60, 62, 64, 66 to pass the pressurized lubricating and sealing fluid between sealing panels 108, 110 and portions of the respective circular ends 68, 70, 72, 74 and 76, 78, 80, 82. Thus, due to the injection of the

14

lubricating and sealing fluid, sealing panels 108, 110 float over the circular ends 68, 70, 72, 74 and 76, 78, 80, 82 at small controllable distances, with little or no physical contact between sealing panels 108, 110 and the circular ends 68, 70, 72, 74 and 76, 78, 80, 82 of rollers 60, 62, 64, 66. Although there is leakage around such a seal arrangement, the amount of leakage is controllable to be small by careful selection of distance tolerances and the lubricating and sealing fluid.

In addition, it is contemplated that main roller 62 also include venting to a differential source, and that continuous web 140, along with membrane 20, is routed to pass through all of the four nips, such as for example, into nip 106, out nip 104, into nip 100 and out nip 102 to increase the dwell time that membrane 20 interacts with continuous web 140.

Fig. 5 shows another variant of the invention, in which end sealing of chamber 112 is improved by locating fluid ports 154 in sealing panels 108, 110 to be near, but not located to face, the ends of the rollers 60, 62, 64, 66. A conduit ring 156 is coupled to ports 154, and is coupled to fluid source 152 via conduit 158, to supply a lubricating and sealing fluid, such as air or water, or some other viscous fluid, into chamber 112 through ports 154. Fluid source 152 is electrically coupled to controller 120 via electrical cable 155, and is controlled thereby. Pressure in chamber 112 forces the added fluid between circular ends 68, 70, 72, 74 and 76, 78, 80, 82 of rollers 60, 62, 64, 66 and sealing panels 108, 110, respectively, allowing sealing panels 108, 110 to float over the circular ends. In this embodiment, leakage is controlled by controlling the spacing between circular ends 68, 70, 72, 74 and 76, 78, 80, 82 of rollers 60, 62, 64, 66 and sealing panels 108, 110, respectively, so that excessive leakage doesn't occur in one area, and so as to prevent excessive wear between the sealing panels 108, 110 and rollers 60, 62, 64, 66.

15

Fig. 6 shows another variant of the invention, in which a main roller 160 having the profile shown would replace main roller 60. Main roller 160 includes a first circular end 162, a second circular end 164, a first cylindrical end surface 166 and a second cylindrical end surface 168, a first inclined annular surface 170, a second inclined annular surface 172 and a cylindrical middle surface 174. First cylindrical end surface 166 is located adjacent first circular end 162 and second cylindrical end surface 168 is located adjacent second circular end 164. Cylindrical middle surface 174 has a circumference smaller than a circumference of first and second cylindrical end surfaces 166, 168. First inclined annular surface 170 provides a transition from cylindrical middle surface 174 to first cylindrical end surface 166, and second inclined annular surface 172 provides a transition from cylindrical middle surface 174 to second cylindrical end surface 168.

A width of cylindrical middle surface 174 is selected to be approximately equal to a width of membrane 20. First and second inclined annular surfaces 170, 172 define a guide path for membrane 20, continuous web 140 and web carrying layer 142. Preferably, each of membrane 20, and web carrying layer 142 includes a pair of tapered outer edges which contact the first and second inclined annular surfaces 170, 172. Most preferably, permeable membrane 20 includes a pair of tapered impermeable longitudinal outer edges 20A, 20B formed adjacent a semipermeable portion 20C to enhance sealing along inclined annular surfaces 170, 172. Also, preferably, web carrying layer 142 includes felt layer 142A and hydrophobic layer 142B. Optionally, web carrying layer 142 may include a pair of impermeable longitudinal outer edges which contact first and second inclined annular surfaces 170, 172.

Fig. 7 schematically illustrates another variant of the invention, in which a press arrangement 200 includes a roller assembly 201 including a plurality of rollers 202, 204, 206,

16

208 arranged in a square pattern for cooperative rotation in processing a first continuous web 209. such as a paper web, riding on a web carrying layer 210 and a second continuous web 212. such as a paper web, riding on a web carrying layer 214. Web carrying layers 210, 214 may be, for example, felt layers.

Each of the rollers 202, 204 are of the type previously described above as main roller 60, and each of the rollers 206, 208 are of the type described above as cap rollers 64, 66, and thus, will not be described again in detail. Also, it is to be understood that sealing panels of the same general type as described above with respect to sealing panels 108 and 110 would be utilized in the manner described above with respect to Figs. 4 and 5 to define a chamber 216. Control and pressure source connections to chamber 216, and associated operation, are as described above with respect to Figs, 1-4, and thus will not be repeated here.

For purposes of this discussion, rollers 202 and 204 will be referred to as main rollers, and rollers 206, 208 will be referred to as cap rollers, although in the present embodiment, rollers 202, 204, 206, 208 are of approximately the same size. Main rollers 202, 204 and cap rollers 206, 208 are positioned to define a plurality roller nips 220, 222, 224, 226 of which based upon a rotation of main roller 202 in the direction depicted by arrow 230, roller nips 220, 224 constitute inlet roller nips of press arrangement 200, and roller nips 222, 226 constitute outlet roller nips.

First continuous web 209 and first web carrying layer 210 enter input nip 220 and are processed through chamber 216 around the circumference of main roller 202. Second continuous web 212 and second web carrying layer 214 enter inlet nip 224 and are processed through chamber 216 around the circumferential surface of main roller 204. First web carrying layer 210, continuous web 209, continuous web 212 and second web carrying layer 214 are processed through outlet nip 222 to form a laminated web 228 made up of continuous webs 209, 212.

During processing, second continuous web 212 remains in contact with first continuous web 209 due to surface tension, or due to venting in main roller 202 by holes, grooves or pores formed in the cylindrical surface of main roller 202. It is contemplated that second continuous web 212 and second web carrying layer 214 could be replaced by a coating layer which would be applied to continuous web 209.

Fig. 8 is a schematic illustration of another embodiment of the invention in which a press arrangement 300 includes a roller assembly 301 including a plurality of rollers 302, 304, 306, 308, 310 and 312 arranged for cooperative rotation in processing a continuous web 314, such as a paper web. Each of the rollers 302 ,304 are of the type previously described as main roller 60 and/or 160, and are fluidly coupled to a differential pressure source in a manner as described above. Rollers 306, 308, 310, 312 are of the type described above with respect to non-vented main and cap rollers, such as main roller 62 and cap roller 64, and thus, will not be described again in detail. Also, sealing panel 316 is of the same general type as described above with respect to sealing panels 108 and 110, and can be utilized in the manner described above with respect to Figs. 4 and 5.

For purposes of this discussion, rollers 302 and 304 will be referred to as main rollers, and rollers 306, 308, 310 and 312 will be referred to as cap rollers based upon their respective primary function within a given chamber with respect to continuous web 314. In the present embodiment, rollers 302, 304, 306, 308, 310 and 312 are of approximately the same size. Main rollers 302, 304 and cap rollers 306, 308, 310, 312 are positioned to define a plurality of roller nips 320, 322, 324, 326, 328, 330, 332, of which based upon a rotation of main roller 302 in the direction depicted by arrow 334, roller nips 320, 326, 330 constitute inlet roller nips of press arrangement 300, roller nips 322, 328, 332 constitute outlet roller nips, and roller nip 324 is a

chamber dividing nip. The orientation and/or size of rollers 302, 304, 306, 308, 310 and 312 may be modified to locate the roller nips at the desired locations and to optimize the efficiency of processing.

Sealing panels 316, together with rollers 302, 304, 306, 308, 310 and 312 define a first chamber 336 and a second chamber 338, wherein each chamber has associated therewith at least one inlet nip and at least one outlet nip.

A first pressure source 340 is fluidly coupled to chamber 336 via conduit 342, and a second pressure source 344 is fluidly coupled to chamber 338 via conduit 346. Conduits 342 and 346 extend from sealing panel 316 into chambers 336 and 338, respectively, to distribute a fluid flow therein. Controller 120 is electrically coupled to pressure source 340 via an electrical cable 348 and is electrically coupled to pressure source 344 via an electrical cable 350. A sensor assembly 352 is electrically connected to controller 120 via electrical cable 354. Sensor assembly 352 is adapted to monitor the pressure and temperature of each of chambers 336, 338.

Press arrangement 300 further includes a first semipermeable membrane 360 and a second semipermeable membrane 362. Membranes 360, 362 interact with the circumferential surfaces of main rollers 302, 304 to define a first expanded nip 364 and a second expanded nip 366. Expanded nip 364 is located in first chamber 336 and expanded nip 366 is located in second chamber 338.

Continuous web 314 includes a first side 370 and a second side 372. While in chamber 336, a fluid flows through continuous web 314 in a first direction from first side 370 to second side 372 at expanded nip 364. While in chamber 338, a fluid flows through continuous web 314 in a second direction, opposite from the first direction, from second side 372 to first side 370 at expanded nip 364. First membrane 360 communicates with first chamber 336 and main roller

302 to apply a mechanical pressing force to continuous web 314 in the first direction, i.e., from first side 370 to second side 372. Second membrane 362 communicates with second chamber 338 and main roller 304 to apply a mechanical pressing force to continuous web 314 in the second direction, i.e. from second side 372 to first side 370. Thus, membranes 360, 362 communicate with pressurized chambers 336, 338, respectively, and main rollers 302, 304, respectively, to simultaneously effect both a predetermined fluid flow and a mechanical pressing force on continuous web 314, in combination, in two directions, to promote enhanced de-watering of continuous web 314. In the present embodiment, main rollers 302, 304 each include at least one void, such as a hole, groove or pore, to effect a pressure differential across continuous web 314.

Preferably, each of first semipermeable membrane 360 and second semipermeable membrane 362 is made of a rubberized fabric about 0.1 inches thick, or less, and is made semipermeable by forming a plurality of holes through the fabric having a size, shape, frequency and/or pattern selected to provide the desired permeability. Preferably, the plurality of holes are formed by a laser. The permeability of each of first semipermeable membrane 360 and second semipermeable membrane 362 is selected to be greater than zero and less than about five CFM per square foot as measured by TAPPI test method TIP 0404-20, and more preferably, to be greater than zero and less than about two CFM per square foot.

In preferred embodiments, press arrangement 300 further includes a first web support layer 361 and a second web support layer 363 positioned, respectively, on opposing sides of continuous web 314. As shown in Fig. 8, first web support layer 361 is positioned between membrane 362 and rollers 302 and 312, and second web support layer 363 is positioned between membrane 360 and rollers 306 and 304. Alternatively, first web support layer 361 can be

20

positioned to lie between continuous web 314 and membrane 362 and second web support layer 363 can be positioned to lie between continuous web 314 and membrane 360. Preferably, each of web support layers 361, 363 is an integral fabric having a felt layer and a hydrophobic layer with a total thickness of about 0.1 inches or less, and is oriented such that the hydrophobic layer faces continuous web 314.

As shown in Fig. 8, expanded nips 364 and 366 are substantially the same length. However, the nip lengths may be of different lengths, which can be effected, for example, by selecting main rollers with differing circumferences, and/or by changing the circumferential size of any one or more of the cap rollers, to effectively change the location of one or more of the roller nips 320, 324 and 328.

The internal pressure of each of first chamber 336 and second chamber 338 are individually controlled by controller 120, and may be pressurized to different pressures. Preferably, chamber 338 is pressurized to a greater pressure than the pressure of chamber 336. Also, in some instances it may be desirable to charge chamber 336 with a first material and charge chamber 338 with a second material different than the first material. Such materials may include dry air, steam, other gas, water, or other fluid.

In addition to controlling the pressures in chambers 336, in some instances it is desirable to control the temperatures of chambers 336, 338 to the same, or possibly different, temperatures. Fig. 8 further shows a temperature regulation unit 374 fluidly coupled via conduits 376, 378 to chambers 336, 338, respectively, to supply a heating or cooling fluid, such as air, to chambers 336, 338. Temperature regulation unit 374 is electrically coupled to controller 120 via electrical cable 380. Controller 120 receives temperature signals representing the temperatures of chambers 336, 338 from sensor assembly 352. Controller 120 then uses these temperatures to

21

generate temperature output signals based upon predefined target temperatures, which are supplied to temperature regulation unit 374. Temperature regulation unit 374 then responds to the temperature output signals to regulate the temperatures of chambers 336, 338. Preferably, the temperature of chamber 338 is controlled to be greater than the temperature of chamber 336.

Alternatively, the temperature regulation of chambers 336, 338 can be effected by regulating the temperature of the fluids supplied by first pressure source 340 and/or second fluid source 344 to chambers 336, 338, respectively. In such a case, temperature regulation unit 374 can be eliminated.

Referring now to Fig. 9, there is schematically shown a press arrangement 450 including a a pressing assembly 452 defining a chamber 454. Chamber 454 includes an inlet 456 and an outlet 458 which guide semipermeable membrane 20, continuous web 140 and web carrying layer 142 into and out of chamber 454.

Pressing assembly 452 includes a U-shaped housing 460 and roller 160 which is arranged to engage U-shaped housing 460 to partially define pressurized chamber 454, and to define inlet 456 and outlet 458. Roller 160, as more fully described above, includes cylindrical middle surface 174 which is in fluid communication with a differential pressure source via conduit 133. Membrane 20, continuous web 140 and web support layer 142 are processed through inlet 456 and outlet 458 of chamber 454, with continuous web 140 being positioned between membrane 20 and web support layer 142.

A pressure source is fluidly coupled to chamber 454 via conduit 132 to pressurize chamber 454 with a fluid, such as a gas or a liquid, which may be heated above ambient temperature. The differential pressure source is coupled via fluid conduit 133 to chamber 454 to effect a flow of fluid through chamber 454 to semipermeable membrane 20. Membrane 20 is

22

positioned adjacent first side 144 of continuous web 140. As more fully set forth above, membrane 20 is structured and adapted to have a permeability which permits a predetermined flow of the fluid therethrough to continuous web 140, and is structured and adapted for communicating with pressurized chamber 454 and the differential pressure source to apply a mechanical pressing force to continuous web 140.

While in pressurized chamber 454, cylindrical middle surface 174 of roller 160 directly supports web support layer 142, which in turn is in contact with second side 146 of continuous web 140. Semipermeable membrane 20 is positioned to be in direct communication with pressurized chamber 454. Cylindrical middle surface 174 includes at least one void in communication with the differential pressure source via conduit 133. Thus, a pressure differential acts on semipermeable membrane 20 and cylindrical middle surface 174 to effect a mechanical pressing force to continuous web 140, and simultaneously, a predetermined flow of fluid flows through semipermeable membrane 20 to, and through, continuous web 140.

Alternatively, no venting via conduit 133 may be required if main roller 160 includes grooved voids, and the grooves communicate with atmospheric pressure. Similarly, venting via conduit 133 may be eliminated if the roller voids, such as blind holes, are large enough, and if they enter into the nip at a pressure lower than chamber pressure. In this case, the voids will act like a differential pressure source until the voids reach the chamber pressure. The void size can be selected to control the efficiency of the de-watering process.

Fig. 10 shows a schematic illustration of a varient of the embodiment of Fig. 9. Shown is a press arrangement 470 including a pressing assembly 472 defining a chamber 474. Chamber 474 includes an inlet 476 and an outlet 478 which guide semipermeable membrane 20, continuous web 140 and web carrying layer 142 into and out of chamber 474.

Pressing assembly 472 includes U-shaped housing 460 and a support shoe 480 which is arranged to engage U-shaped housing 460 to partially define pressurized chamber 474, and to define inlet 476 and outlet 478. Support shoe 480 includes a support surface 482, and one or more passages 484 (depicted by dashed lines) which extend from support surface 482 to differential pressure conduit 133. Support surface 482 may be made up of a plurality of spaced apart support plates, or vertically arranged support blades, with passages 484 being formed between adjacent support plates, or support blades, respectively. Alternatively, support shoe 480 may be a unitary plate member having at least one void, and preferably a plurality of voids, such as pores, through holes, grooves, slots, etc., which are in fluid communication with the differential pressure source via conduit 133, or directly with the atmosphere.

A pressure source is fluidly coupled to chamber 474 via conduit 132 to pressurize chamber 474 with a fluid, such as a gas, a liquid or solution, which may be heated above ambient temperature. The differential pressure source is coupled via fluid conduit 133 to chamber 474 to effect a flow of fluid through chamber 474 to semipermeable membrane 20. Membrane 20 is positioned adjacent first side 144 of continuous web 140. As more fully set forth above, membrane 20 is structured and adapted to have a permeability which permits a predetermined flow of the fluid therethrough to continuous web 140, and is structured and adapted for communicating with the pressurized chamber 474 and the differential pressure source to apply a mechanical pressing force to continuous web 140.

Membrane 20, continuous web 140 and web support layer 142 are processed through inlet 476 and outlet 478 of chamber 474, with continuous web 140 being positioned between membrane 20 and web support layer 142. While in pressurized chamber 474, support surface 482 directly supports web support layer 142, which in turn is in contact with second side 146 of

continuous web 140. Semipermeable membrane 20 is positioned to be in direct communication with pressurized chamber 474. As stated above, support surface 482 includes at least one void/passage which is in communication with the differential pressure source via conduit 133. Thus, a pressure differential is created between chamber 474 and support surface 482 to effect a mechanical pressing force to continuous web 140 via semipermeable membrane 20, and simultaneously, a predetermined flow of the fluid is provided through semipermeable membrane 20 to, and through, continuous web 140.

While the invention has been described as an apparatus for de-watering a continuous web, it is contemplated that the invention could be modified to form a continuous web, or fiber web such as a paper web, by utilizing the fluid source, such as fluid source 124 of Fig. 1, feed a sheet forming fabric in the path generally followed by the continuous web of the previous embodiments. A slurry, such as a fiber slurry, is ejected onto the forming fabric in one or more pressurized chambers. The fiber slurry includes fibers, such as wood fibers, suspended in a liquid, such as water. The fiber slurry is ejected onto the forming fabric from conduit 132 which extends into the chamber.

As illustratively shown in Fig. 11, preferably, within pressurized chamber 112, conduit 132 forms manifold having a plurality of distribution holes 486 which extend across the width W of forming fabric 488. The fiber slurry 490 is ejected onto forming fabric 488 in chamber 112. The fiber web is formed on the sheet forming fabric 488 on a side opposite to main roller 60 which is vented, e.g., by the inclusion of at least one of a groove, a hole and pore in the circumferential surface of the roller. The rotation of the rollers forming walls of the chamber produce a naturally turbulent region between the rollers which aids in breaking up flocks in the fiber slurry.

Thus, the present invention has a forming area which is shortened over that of a typical headbox arrangement, and the forming process can be controlled by the application of pressure within the chamber. The present invention can be joined seamlessly with a cluster press to form a compact paper machine. In addition, the present invention can incorporate multiple chambers to form a multi-ply sheet, whereby each layer of the multiple layers is formed on a forming fabric in a respective one of the multiple chambers, and wherein de-watering occurs following the initial formation of each layer. Such an arrangement provides the flexibility of forming one or more of the multiple layers from a material different from the material forming another layer of the multiple layers.

While this invention has been described as having a preferred design, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.